260Oct23

Thursday, October 26, 2023   6:02 PM

Todays class

1. Vector control system ... IM.
2. Inner & outer loop ...
3. Vector control of PM-SM.

① space vector equations of IM in stator coordinates.

② $\vec{\psi}_r$, $\vec{i}_s$ ... keep $\vec{\psi}_r$ .. constant.

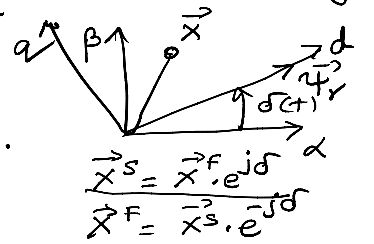
$$\boxed{\begin{aligned} k_r &= \frac{l_h}{l_r} \\ \sigma &= 1 - \frac{l_h^2}{l_s l_r} \end{aligned}}$$

$$\vec{v}_s = r_s \cdot \vec{i}_s + k_r \frac{d\vec{\psi}_r}{d\tau} + \sigma l_s \cdot \frac{d\vec{i}_s}{d\tau} \quad \text{.... Stator system}$$

$$0 = r_r \cdot \vec{i}_r^{\,s} - j\omega \psi_r + \frac{d\vec{\psi}_r}{d\tau} \quad \text{... rotor system}$$

Rotor flux field orientation

Convert the rotor equation into Field.



$$\frac{d\delta(t)}{dt} = \omega_s$$

$$\vec{x}^{\,s} = \vec{x}^{\,F} \cdot e^{j\delta}$$

$$\vec{x}^{\,F} = \vec{x}^{\,s} \cdot e^{-j\delta}$$

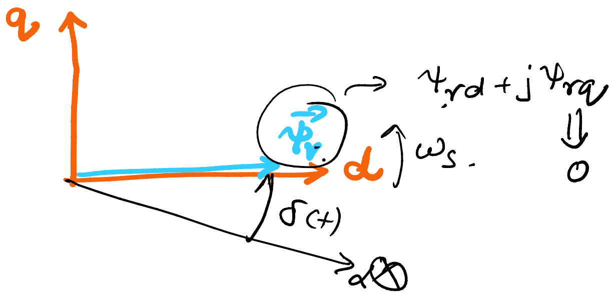
$$0 = r_r \cdot \vec{i}_r^{\,F} e^{+j\delta} - j\omega \vec{\psi}_r^{\,F} \cdot e^{+j\delta} + \frac{d(\vec{\psi}_r^{\,F} \cdot e^{+j\delta})}{d\tau}$$

$$= r_r \cdot \vec{i}_r^{\,F} \cdot \cancel{e^{j\delta}} - j\omega \vec{\psi}^{\,F} \cdot \cancel{e^{j\delta}} + \vec{\psi}^{\,F} \cdot j\omega_s \cdot \cancel{e^{j\delta}} + \frac{d\vec{\psi}_r^{\,F}}{d\tau} \cdot \cancel{e^{j\delta}}$$

$$\boxed{0 = r_r \cdot \vec{i}_r^{\,F} + j\omega_r \vec{\psi}_r^{\,F} + \frac{d\vec{\psi}_r^{\,F}}{d\tau}}$$

Field coordinates

d, q



$$= r_r \cdot \frac{1}{l_r}\left[\vec{\psi}_r^{\,F} - l_h \cdot \vec{i}_s^{\,F}\right] + j\omega_r \vec{\psi}_r + \frac{d\vec{\psi}_r}{d\tau}$$

$$= \frac{1}{\tau_r} \vec{\psi}_r^{\,F} - \frac{l_h}{\tau_r} \cdot \vec{i}_s^{\,F} + j\omega_r \vec{\psi}_r + \frac{d\vec{\psi}_r}{d\tau}$$

$$= \frac{1}{\tau_r}[\psi_{rd}] - \frac{l_h}{\tau_r}[i_{sd} + j\, i_{sq}] + j\omega_r[\psi_{rd}] + \frac{d\psi_{rd}}{d\tau}$$

Stator coordinates

$$0 = r_r \cdot \vec{i}_r - j\omega \vec{\psi}_r + \frac{d\vec{\psi}_r}{d\tau}$$

$$\psi_r = l_r \cdot \vec{i}_r + l_h \vec{i}_s$$

$$\therefore \; i_r = \frac{1}{l_r}[\psi_r - l_h i_s]$$

$$\tau_r = \frac{l_r}{r_r}$$

$$= \frac{r_r}{l_r}[\psi_r - l_h \cdot i_s] - j\omega \vec{\psi}_r + \frac{d\vec{\psi}_r}{d\tau}$$

$$0 = \frac{1}{\tau_r}(1 - j\omega\tau_r)\vec{\psi}_r + \frac{d\vec{\psi}_r}{d\tau} - \frac{l_h}{\tau_r}\vec{i}_s$$

d

$$\frac{d\psi_{rd}}{d\tau} + \frac{\psi_{rd}}{\tau_r} - \frac{l_h}{\tau_r} i_{sd} = 0$$

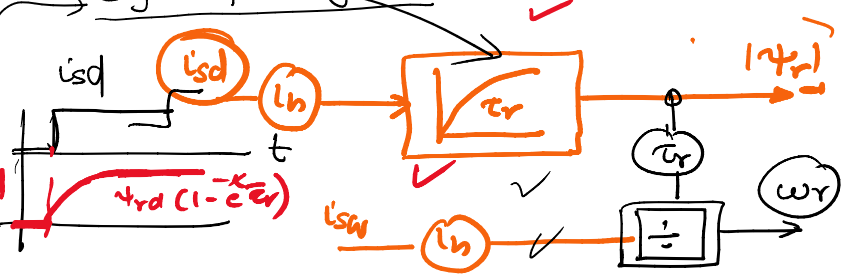
q ...

$$\omega_r \psi_{rd} - \frac{l_h}{\tau_r} \cdot i_{sq} = 0$$

→ Signal flow graph

$$\tau_r \frac{d\psi_{rd}}{d\tau} + \psi_{rd} = L_h i_{sd}.$$

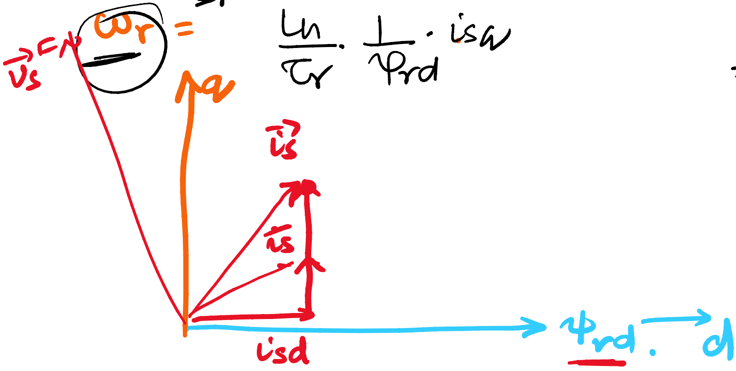
Signal flow graph



$$\omega_r \cdot \psi_{rd}\, \tau_r = L_h i_{sq}$$

$$\omega_r = \frac{L_h}{\tau_r} \cdot \frac{1}{\psi_{rd}} \cdot i_{sq}$$

$$\omega_r = \omega_s - \omega \quad (S) \to \text{load}.$$



$$m_e = k_r \vec{\psi}_r^{\,F} \times \vec{i}_s^{\,F}$$

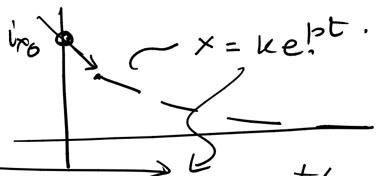
$$= k_r \left[(\psi_{rd} + j0) \times (i_{sd} + j i_{sq}) \right]$$

$$\boxed{m_e = k_r \cdot \psi_{rd} \cdot i_{sq}}$$

i_{sd} → controls — ψ_{rd} -- magnetization

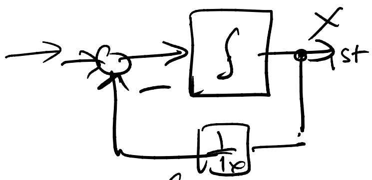
Stator equation in field coordinates

$$T_x \frac{dx}{dt} + x = 0 \quad \text{hon}$$



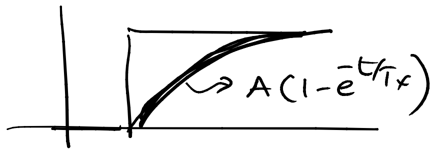
$$\therefore \frac{dx}{dt} = -\frac{x}{T_x}$$

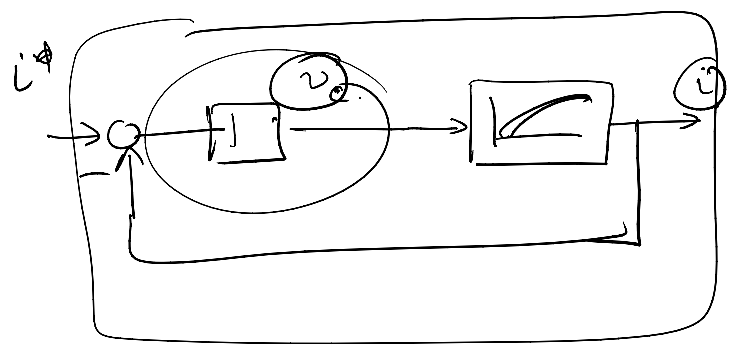
$$x = ke^{-t/T_x}$$



1st order system.

$$T_x \cdot \frac{dx}{dt} + x = A.$$





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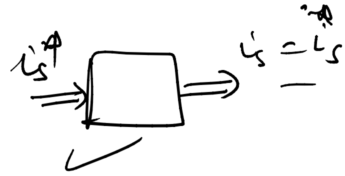
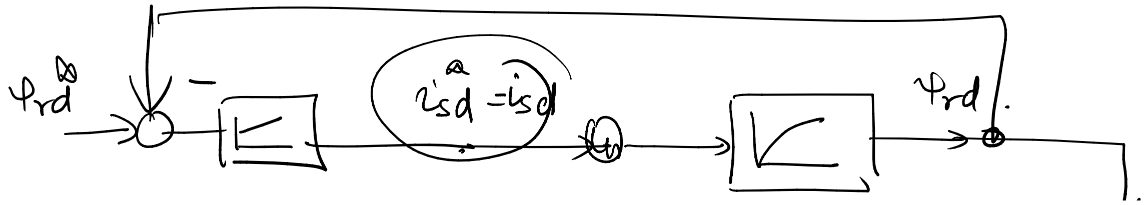
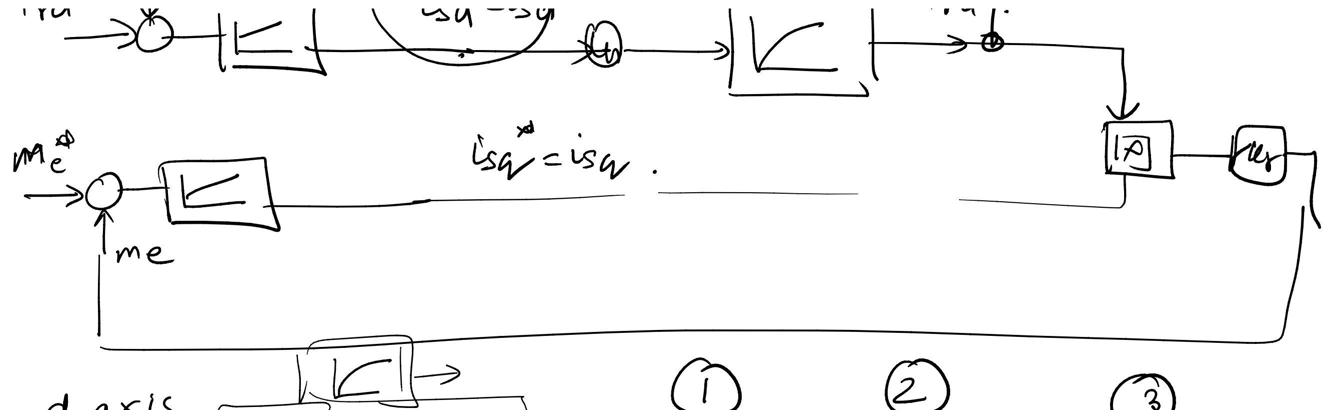


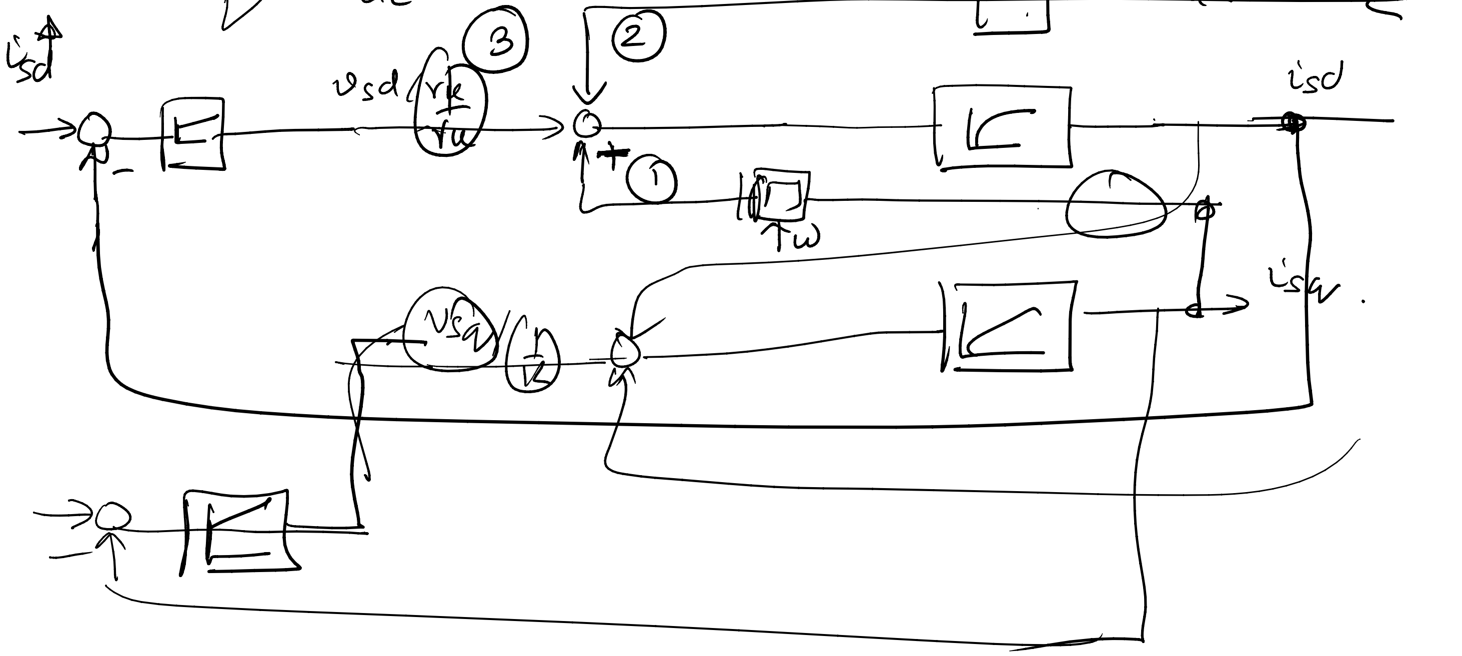




d-axis

$$\boxed{\tau_k \cdot \frac{di_{sd}}{dt} + i_{sd}} = \overset{①}{\omega_s \cdot i_{sq} \tau_k} + \overset{②}{\frac{k_r \cdot \tau_k}{\sigma l_s \cdot \tau_r} \cdot \psi_r} + \overset{③}{\frac{v_{sd}}{r_k}}$$

$$\tau_k \cdot \frac{di_{sq}}{dt} + i_{sq} = -\omega_s \cdot i_{sd} \cdot \tau_k - \frac{k_r}{\sigma l_s} \omega \cdot \psi_r \tau_k + \frac{v_{sq}}{r_k}$$



PMSM

$$\psi_{sd} = l_d \cdot i_{sd} + \psi_{rm}$$

$$m_e = \underbrace{\psi_{rm} \cdot i_{sq}}_{>0} + \underbrace{(l_d - l_q)}_{<0} \overset{<0}{i_{sd}} \underbrace{i_{sq}}_{>0}.$$